This would suggest our having recourse to the corpuscles of which the investigation is now beginning and may be the main subject of physical research during the next generation. But here, if we accept the theoretical result of Professor J. J. Thomson, we meet with the difficulty that these entities can not travel with a greater speed than that of light. Under these circumstances nothing seems left for us in the present state of our knowledge but to turn over to our successors the problem of explaining the phenomena.

The main point I desire to bring out in this review is the tendency which it shows towards unification in physical research. Heretofore differentiation—the subdivision of workers into a continually increasing number of groups of specialists—has been the rule. Now we see a coming together of what, at first sight, seem the most widely separated spheres of activity. What two branches could be more widely separated than that of stellar statistics, embracing the whole universe within its scope, and the study of these newly-discovered emanations, the product of our laboratories, which seem to show the existence of corpuscles smaller than the atoms of matter? And yet, the phenomena which we have reviewed, especially the relation of terrestrial magnetism to the solar activity, and the formation of nebulous masses around the new stars, can be accounted for only by emanations or forms of force, having probably some similarity with the corpuscles, electrons and rays which we are now producing in our laboratories. The nineteenth century, in passing away, points with pride to what it has done. It has become a word to symbolize what is most important in human progress. Yet, perhaps its greatest glory may prove to be that the last thing it did was to lay a foundation for the physical science of the twentieth century. What shall be discovered in the new fields is, at present, as far without our ken as were the modern developments of electricity without the ken of the investigators of one hundred years ago. We can not guarantee any special discovery. What lies before us is an illimitable field, the existence of which was scarcely suspected ten years ago, the exploration of which may well absorb the activities of our physical laboratories, and of the great mass of our astronomical observers and investigators for as many generations as were required to bring electrical science to its present state. We of the older generation can not hope to see more than the beginning of this development, and can only tender our best wishes and most hearty congratulations to the younger school whose function it will be to explore the limitless field now before it.

S. NEWCOMB.

PLANS OF THE NEW BUILDINGS FOR THE NATIONAL BUREAU OF STANDARDS.*

THE work for which the National Bureau of Standards was established includes research and testing in the domain of physics, extending into the field of chemistry on the one hand and of engineering on the other. The union of research and testing in one institution is of supreme importance, the investigations being, of course, primarily designed to carry the work of standardization and testing to the highest possible efficiency. The Physikalisch-Technische Reichsanstalt is an illustrious example before all the world of how much can be accomplished where research and testing are combined in one institution; and that the union should be intimate is further shown by the fact that more or less research is carried on in the second, or technical, division of the Reichsanstalt, instead of being confined to the first

* A paper read before the Philosophical Society of Washington, October 25, 1902.

division, which is especially the division of research.

At the very outset the director of the Bureau of Standards realized the advantages of this intimate association of research and testing, and no attempt was made or will be made to separate them into two divisions. The laboratory requirements are, therefore, those of a research laboratory plus whatever special facilities may be needed for commercial testing. In addition to the workers themselves there is then required: (1) A suitable place in which to work; (2) an equipment of apparatus, tools and machines; and (3) facilities and appliances for providing the proper conditions for experimental work.

To meet these requirements Congress has already authorized the expenditure of $25,000 for a site, $325,000 for buildings, and $40,000 for equipment. Further appropriations for equipment and personnel will be made as needed.

The site lies in the northwestern suburbs of Washington, about three and one half miles from the Treasury and 1,000 feet from Connecticut Avenue, just north of Cleveland Park. It is 350 feet above the Potomac, and is the highest ground in that vicinity. Complete freedom from the jarring of street traffic is assured, and magnetic disturbances due to the only electric railway in that immediate region will be very slight.

1. Two buildings have been planned, one of which is now under construction; the plans for the other are completed and its construction will soon begin. The larger of the two, which is called the physical building, will provide for that part of the experimental work which ought to be kept free from mechanical and magnetic disturbances, and to this end will contain scarcely any machinery. It will also contain the offices for administration and the library, and a well-equipped chemical laboratory. The mechanical laboratory contains the mechanical plant, instrument shop, and laboratories for the heavier kinds of experimental work, where considerable power or large electric currents are required. These two buildings are to be united by a spacious tunnel, through which air ducts, steam, gas and water pipes, and electric circuits are to be carried from the mechanical to the physical laboratory. The mechanical laboratory was begun last July, and will cost about $125,000, including the heating and ventilating plant. The physical building will cost about $200,000 exclusive of equipment and including the connecting tunnel.

2. Considerable progress has already been made in procuring an equipment of apparatus, tools and machines. In addition to the fifteen rooms in the U. S. Coast and Geodetic Survey buildings, occupied by the bureau last year, a large four-story residence at 235 New Jersey Avenue, SE., has recently been leased and equipped as a temporary instrument shop and laboratory. A small brick building in the rear has been converted into an engine and dynamo room, and in the basement of the house a storage battery room and a second dynamo room, the latter for a distributing switchboard and experimental alternators, have been fitted up. A storage battery of 132 cells, of 200 ampère hours capacity, furnishes power for current and lighting and experimental purposes. A low voltage battery giving 1,000 ampères, and two high voltage batteries of 1,000 cells each, have also been provided. During the past year the director and two other officers of the bureau (Drs. Wolff and Waidner) have visited the principal government laboratories and instrument makers of Europe. The instrument shop is well

equipped with motor-driven machines and hand tools, and two mechanicians and a carpenter are now at work. The apparatus and machinery now in use in the temporary quarters is a part of the permanent equipment of the new buildings. A considerable sum of money will, of course, be needed to complete the equipment.

3. The facilities and appliances for carrying on an experiment under the proper conditions are more difficult to secure than the apparatus itself. In general, laboratory rooms should be well lighted and ventilated, and their temperature should be under control. The windows should be double, in order that the space near the windows (often the most valuable in the laboratory) may be warmer in cold weather and cooler in warm weather, and freer from drafts of air, than would be the case with single windows. It should be possible quickly and conveniently to darken many if not all the rooms. The temperature of the laboratory should be automatically controlled by thermostats, so that any temperature (within certain limits) which may be required by a particular experiment or investigation may be maintained, both day and night if necessary for any desired period. The humidity of the air should be low, so that moisture developed in the room either by respiration or evaporation may be absorbed by the air and carried away instead of depositing on the walls and furniture of the room and apparatus. These last considerations, the control of the temperature and humidity of the air, are vital. Many kinds of work can, ordinarily, be done only in the winter months, because summer temperature and summer humidity can not be controlled. This involves not only long delays, but perhaps a large amount of extra labor. This is perhaps oftenest the case in electrical work, but in many other instances it is equally important. Apparatus, tools and machines often suffer by rusting in summer, in spite of the fact that the attendant means to be careful. Hence, in a laboratory where work is to be carried on during the entire year, and where a large quantity of valuable apparatus and instruments of precision are in use, and where, in addition, valuable apparatus is to be received from outside for testing, the necessity of controlling the humidity as well as the temperature of the room is evident.

The temperature of a room may be automatically controlled by means of a thermostat, using either steam or hot air for heating. Hot air, however, possesses three important advantages over steam. In the first place, steam pipes occupy valuable space in a laboratory, usually near the windows or along the walls, where apparatus or benches would otherwise be placed. If they are of iron, their magnetization by the earth's field changes with their temperature, and since the temperature of the room is regulated automatically by shutting off and readmitting the steam, this causes frequent and annoying changes in the magnetic field within the room. In the second place, heating by air affords the best possible ventilation, which is apt to be insufficient in a steam-heated building. And in the third place, heating by air enables the temperature to be automatically controlled in the summer as well as in winter if facilities are provided for cooling the air, and at the same time the humidity may be controlled by partially drying the air. The air of an unventilated laboratory soon becomes saturated with moisture due to respiration and evaporation; and if it be ventilated by allowing hot, moist air from without to enter, the humidity rises as the temperature falls

and the air is unable to carry away moisture generated in the laboratory.

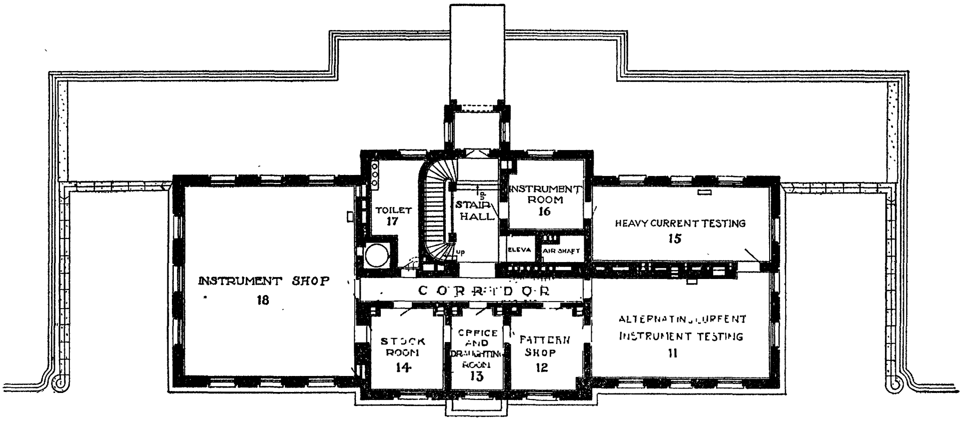
In heating a building by the double-duct system, hot air from one duct is mixed with cooler, tempered air from a second duct in such proportions as to hold the temperature of the room constant, the proportions of the hot and tempered air being regulated by a pair of dampers, the latter being automatically controlled by means of a thermostat. Each room of a building, therefore, has its own supply flue, regulating dampers and thermostat. The latter may be set at any desired temperature within the range of the apparatus. If now in hot weather the hot-air duct of winter carries air taken from out of doors, say at 90° F., and the tempered-air duct carries artificially cooled air, say at 60°, a mixture of the two may give a room temperature of 75° when the temperature would otherwise be 80° or 85°. And the thermostat will adjust automatically the proportions of cooled and uncooled air, so as to hold this temperature constant, thus preventing the usual gradual increase of temperature as the day progresses. By a readjustment of the thermostat any other constant temperature can be secured, provided it is within the range of the system.

Not only will this system make possible automatic temperature control in summer—a most important end in itself—but it will also secure a humidity control. For by cooling air its moisture is partly removed, and by lowering its temperature to the freezing point it is very largely removed. In order to remove as much moisture as possible, it is intended to overcool the air and then partly warm it up again, and this may be done economically by means of a heat exchanger, *i. e.*, air on its way to the cooling chamber gives up heat through a thin metal wall to the overcooled air coming from the cooling chamber; a given refrigerating capacity will thus remove the maximum quantity of moisture, so that the percentage humidity of the air may be no greater at the lower room temperature than, under normal circumstances, it would be at the higher temperature.

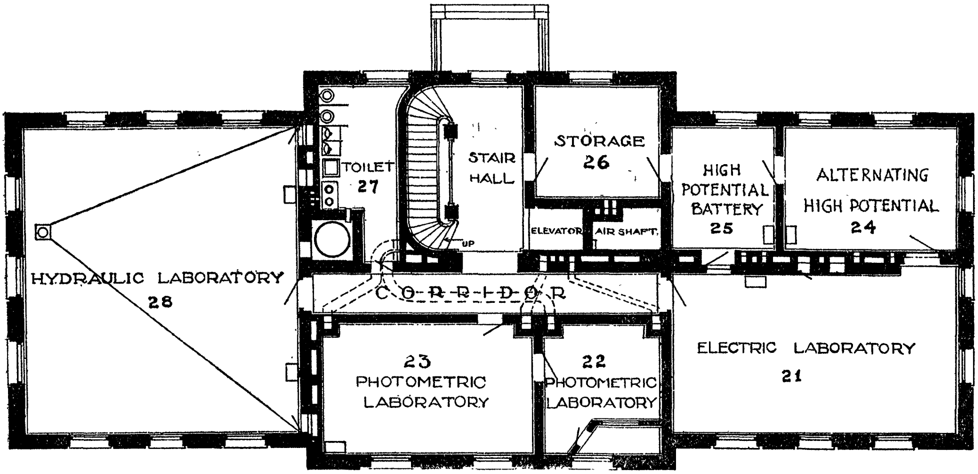
With this system of heating in winter and cooling in summer, with automatic temperature control the year round, with excess of moisture simultaneously removed by refrigeration, and dust from the fresh air taken out by filters, the double windows of the laboratory will be kept tightly closed in summer as in winter, and an atmosphere favorable for experimentation may at any time be secured. The closed double windows will also effectually keep out dust and dirt, two of the enemies of the experimentalist. With gas, compressed air, vacuum, hot and cold water, ice water and distilled water always at hand; with cold brine, carbon dioxide and liquid air always available for low temperatures, and gas and electric furnaces available for high temperatures; with direct electric currents, at potentials up to 20,000 volts and currents up to 20,000 ampères, and still higher alternating voltages and larger alternating currents always available, it is believed that the facilities and appliances necessary for carrying on a wide range of experiments under favorable conditions will be fairly well realized.

THE MECHANICAL LABORATORY.

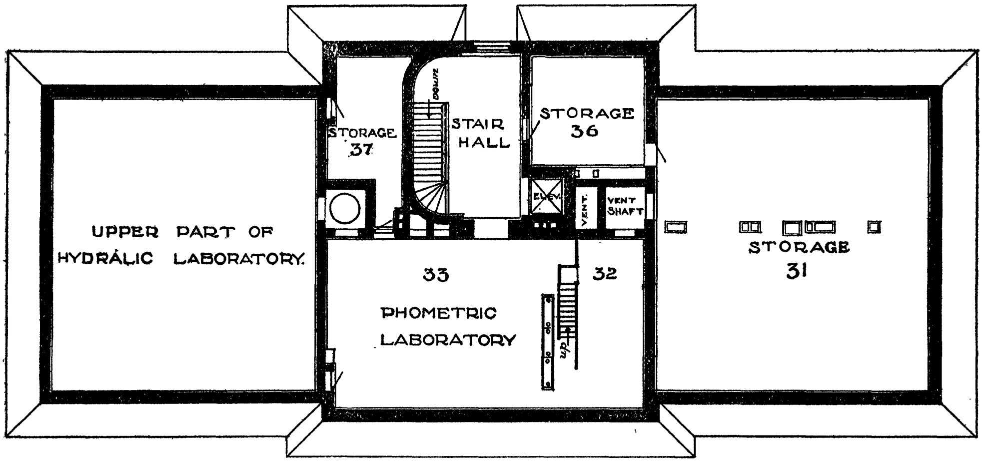
The mechanical laboratory is being built of dark red brick, trimmed with Indiana limestone. It stands on ground sloping toward the north, so that the basement story is wholly above ground on the north, but comes only a few feet above ground on the south. The building is 135 feet long east and west, and 48 feet wide north and



FIRST FLOOR PLAN.



SECOND FLOOR PLAN.



ATTIC FLOOR PLAN.
THE MECHANICAL LABORATORY.

south at the ends, and 58 feet in the central portion. An extension of the basement, wholly below the ground level on the south, is 20 feet wide and projects 25 feet east and west beyond the main portion of the building. This increases the floor area of the basement by 50 per cent., affording ample accommodation for the mechanical plant on this floor.

The boiler room is 42 feet square and 19 feet high, the floor being 5 feet below the engine room floor, and, like the engine and dynamo room, it is lined with white enameled brick. Two water-tube boilers, of 125 horse-power each, are to be installed, and space will be reserved for two other, giving a final capacity of 500 horse-power. The boilers will be fed by automatic stokers, and induced draft will be furnished by a pair of blowers, driven by small steam-engines so governed as automatically to hold a constant steam pressure in the boilers. The smoke flue extends only a little above the roof, and the furnaces will be operated to give as nearly as possible smokeless combustion. Water and air pumps, filters, boiler feed pumps, pressure tanks and other auxiliary apparatus will be located on a platform at the north side of the boiler room, on the engine floor level.

The engine and dynamo room is 87 feet long, and has an average width of 24 feet. The end toward the boiler room will contain two 80-horse-power high-speed steam-engines, each directly connected to two 25-kilowatt dynamos, each giving 200 ampères at 125 volts and connected in a three-wire system, the total capacity, therefore, amounting to 100 kilowatts. Space is reserved for a third engine of 160 horse-power, to drive generators of 100 kilowatts capacity. The western half of this room will be occupied by a number of alternating-current dynamos directly driven by electric motors. These will furnish singlephase and polyphase current for experimental purposes. Several such machines are now being constructed, and others are yet to be ordered. There will be machines with smooth-core armatures and specially shaped pole pieces to give sine waves, others to give distorted waves, and still others to give several harmonic waves which may be combined in various ways to give different wave forms. On the south side of the engine room a switchboard will carry the controlling apparatus for all these dynamos and motors, and also for several storage batteries, and for distributing current to the various laboratory rooms of both buildings. Both live and exhaust steam pipes will be located in the subbasement under the engine room floor.

The refrigerating room is 41×18 feet, and will contain an ammonia refrigerating machine, a liquid-air machine, and a small ice-making plant. The refrigerating machine will have a capacity equivalent to the melting of thirty tons of ice per day. A large tank, filled with calcium chloride brine, will be placed in a room in the subbasement just under the refrigerating machine, and will enable 'cold' to be stored equivalent to ten tons of ice. This may be used at night, when the refrigerating machine is not running, or may be used to supplement the machine in the hottest part of the day, if necessary.

The storage battery room is 61 feet long, and will contain several batteries, which will furnish current to motors driving alternators, ventilating fans, the machines of the instrument shop, lights in the buildings when the engines are not running, and current for experimental purposes.

The air-cooling chamber will contain a large quantity of iron pipe through which cold brine will be pumped, and the air to

be cooled will be blown over these coils of pipe. On one side of this cold room, space will be reserved for placing apparatus which it may be desired to cool, or to perform an experiment at the low temperature of this room. The hall in the center of the basement, which is ten feet wide, leads directly into the tunnel, which is twelve feet wide and on the same level. This tunnel leads directly into the basement of the physical laboratory, located about 175 feet to the south. The heating chamber will contain two banks of steam coils, a larger or 'heating' coil, and a smaller or 'tempering' coil. Air passing through the first is drawn into fan No. 1, while air passing through the second goes along the direction of the dotted line into fan No. 2. When it is desired to cool the air, the latter is diverted and goes along the course of the solid arrows through the cooling chamber to fan No. 2. Each fan has a double discharge, about three fifths of the air passing out of the upper outlet, toward the south and through the tunnel to the physical building, and two fifths going through the lower outlet under the floor of the corridor, to be distributed to the flues of the mechanical building. These blowers are operated by electric motors, and may be driven at different speeds.

The gas machine will produce a gas from gasoline better suited for furnace work, hardening, tempering, etc., than ordinary illuminating gas. This will be piped to all the laboratory rooms.

The large room on the first floor, just above the boiler room, is the instrument shop. This is an important feature of any physical laboratory where research is carried on. Four or five lathes of different sizes and styles, a universal milling machine, shaper, drill press, grinder, circular saw and other machines will be installed, and a complete equipment of hand tools provided. The stock room, drafting room, and pattern shop belong to the instrument shop.

At the instrument room on this floor, instruments for testing will be received and shipped, and apparatus and supplies of the bureau will be received. The heavy current testing laboratory will be provided with eight large storage cells, which, when joined in parallel, will give a current up to 20,000 ampères. They will be charged in series, and may be discharged singly or together in any combination. Shunts and recording wattmeters for heavy current will be tested here. The adjacent room, which is directly over the alternating generator, will be used for testing alternating-current instruments. This will sometimes include an examination of their behavior on different loads, at different temperatures, with currents of different frequencies, different power factors, and different wave shapes. Complete specifications of these factors will be supplied when desired with the results of the test.

Immediately above this room on the second floor, is another electrical laboratory room for alternating- and direct-current experiments, and the magnetic properties of iron, study of transformers, condensers, and cables, under relatively high electromotive forces. Room 24, adjacent, will contain transformers for obtaining still higher alternating voltages for testing insulation resistances; and instruments for measuring alternating voltages up to 50,000 volts or higher will be tested here. Room 25 will contain a storage battery of small cells giving potentials up to 20,000 volts and currents up to 1 ampère at this voltage. Rooms 22 and 23 are to be used for the photometric study and calibration of incandescent lamps, gas lamps, Nernst lamps, etc. Immediately above, on the

attic floor, is a large room for arc-lamp photometry. The hydraulic laboratory extends through the second and attic stories, giving a maximum height of over 25 feet. It will be used for testing gas and water meters, pressure gauges, anemometers, steam indicator springs, etc. Provision has been made for a mercury column in the elevator shaft, so that it can be observed from the elevator platform.

Fresh air taken into the building through an open window on the north side of the second floor (adjacent to one of the photometric rooms) passed up to the filters above, then down the air shaft to the heating and cooling coils of the basement, and thence to the blowers.

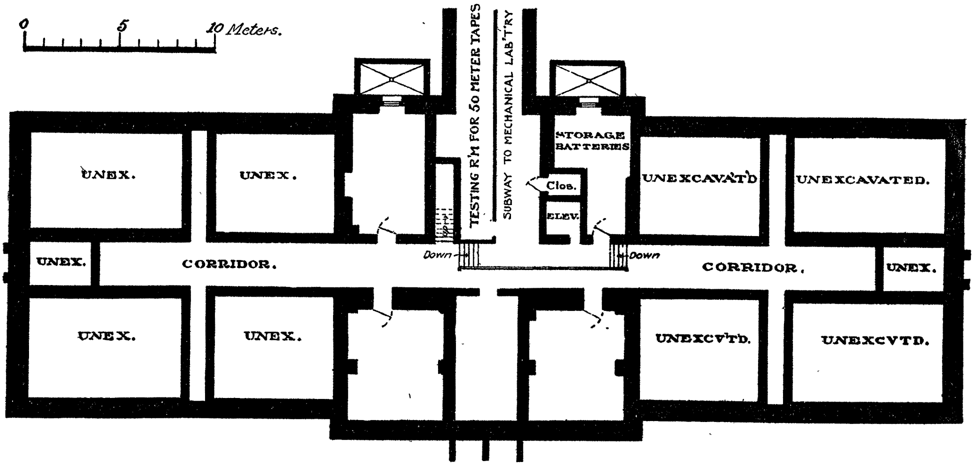
THE PHYSICAL LABORATORY.

The physical building, like the mechanical building, will be built of dark red brick and Indiana limestone, the first story being entirely of stone and the upper stories trimmed with stone. The building is 172 feet long, 55 feet wide, and four stories high, besides a spacious attic story. It faces the south, overlooking the city of Washington.

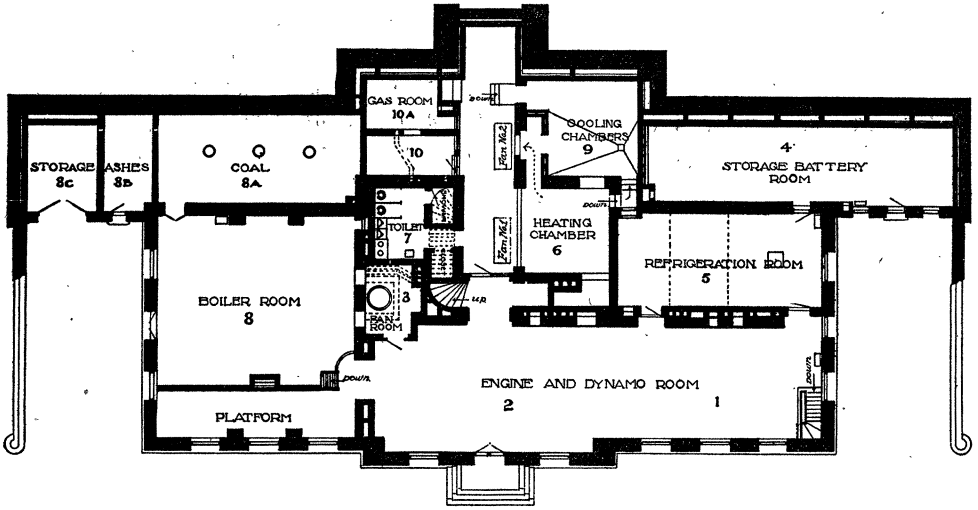
The corridor extends the entire length of the first floor, and the exterior of the building is so designed that if, in the future, additional buildings should be needed, they may be placed one on the east and the other on the west of this building, and connected to it by an arcade opening into the corridor of the first floor. A basement is excavated only under the central portion of the building, and under the corridor, the four large rooms at either end of the ground floor have concrete floors upon which piers may be built as they are found necessary. In one of the basement rooms a storage battery will be installed; the others will be used as constant-temperature rooms for experimental purposes whenever they are needed. Room 4 is a constant temperature room, which will contain the standards of the bureau, and Rooms 13 and 17 are constant-temperature rooms for experimental purposes. All of the rooms of this floor and the floor above, however, will be practically constant-temperature rooms. For with automatic temperature control the temperature can be maintained as nearly constant in these rooms (which have heavy walls and tight double windows) as it could be in any inside or underground room where an observer is working. For the presence of the observer and the heat due to artificial light will disturb the otherwise constant temperature as much or more than the fluctuations in temperature of a room having automatic temperature control. For those cases where a machine or a piece of apparatus is operated without the presence of an observer, as for example a dividing engine, an underground or inside room is better, and several of these have been provided.

A massive-walled, dark, unventilated constant-temperature room is sure to be damp, and is a very poor place for experimental work; there are no such rooms in this building. All of the so-called constant temperature rooms are provided with forced ventilation, although the ventilating air current can be cut off when desired.

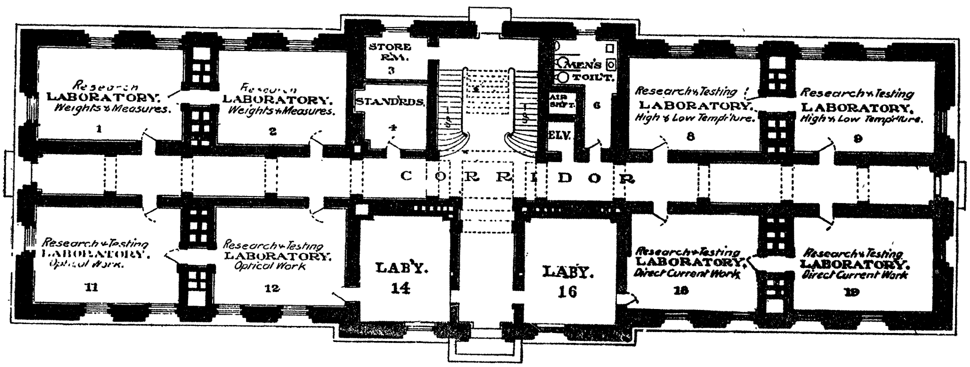
Between Rooms 1 and 2, next to the outer wall, is a vertical shaft three feet square, extending from the basement to the attic, and in corresponding positions are three similar shafts in the other three quarters of the building. All the pipes for distributing gas, compressed air, and vacuum, hot and cold water, ice water, distilled water, cold brine, and all the electric wiring for lighting and experimental purposes are carried up through these



BASEMENT PLAN.



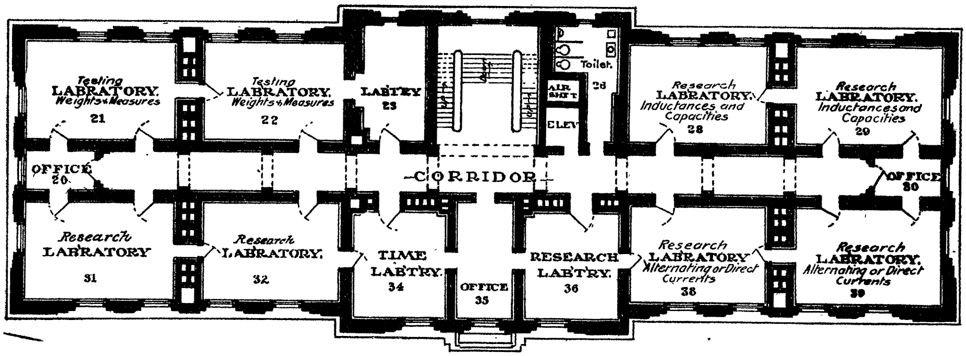
BASEMENT FLOOR PLAN.



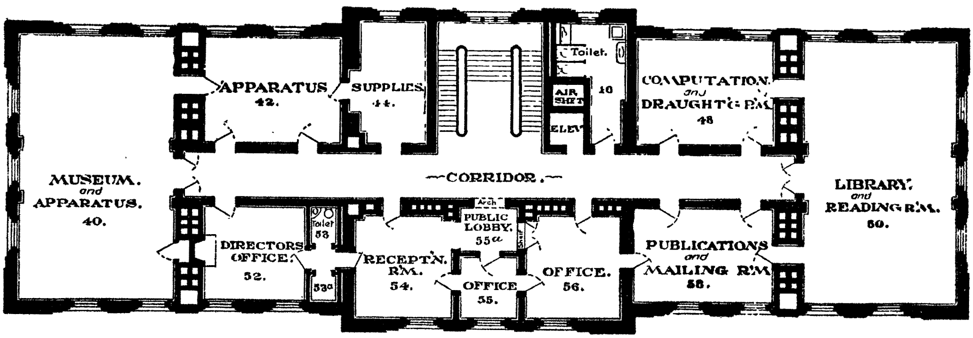
GROUND FLOOR PLAN.

THE PHYSICAL LABORATORY.

shafts. A door opens into each shaft on each floor, making everything accessible without the main pipes and wires being exposed in the laboratories. On each floor branches are brought out from the water pipes to the sinks, from the air and gas pipes to work tables, and from the distributing wires in the shaft to a small switchboard, there being one such switch-



· 2ND. FLOOR PLAN.



3rd FLOOR PLAN.

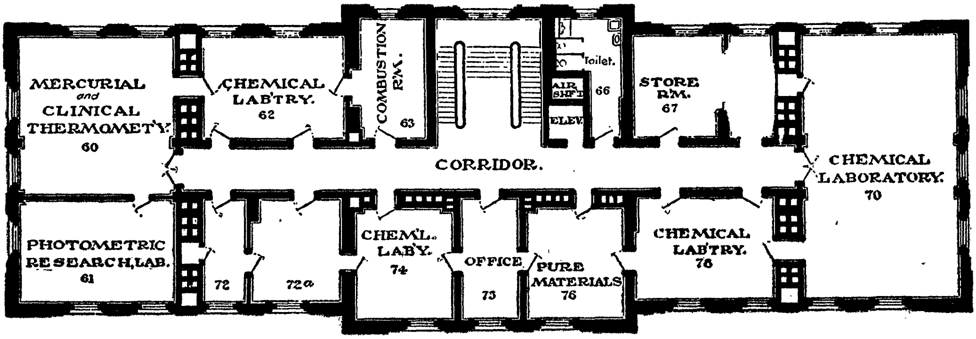
board for each suite of two or three rooms in each quarter of the building. The wires connected to these small switchboards run to a main switchboard near the north door of the first floor, and thence trunk lines run through the tunnel to the distributing switchboard of the dynamic room. Thus, through these two main switchboards and a laboratory board any circuit in any laboratory room may be connected to any other circuit in any other laboratory room or to any battery or generator in the mechanical building. The storage battery in the basement will be so connected to the main switchboard that any number of cells from one to the total number may be joined to any laboratory circuit, and an auto-transformer will similarly give any alternating voltage required. Alternating currents of different phases and frequencies may be had at any place by connecting to the proper machine in the dynamo room. An experimenter can then be supplied with any particular kind of electric current by telephoning to the engineer. The pipes and wires are carried to the foot of these vertical shafts through the basement and tunnels which extend under the flues of the partitions

between Rooms 1 and 2, etc. Room 1 is 18 × 28 feet, and Room 2 is 18 × 25 feet.

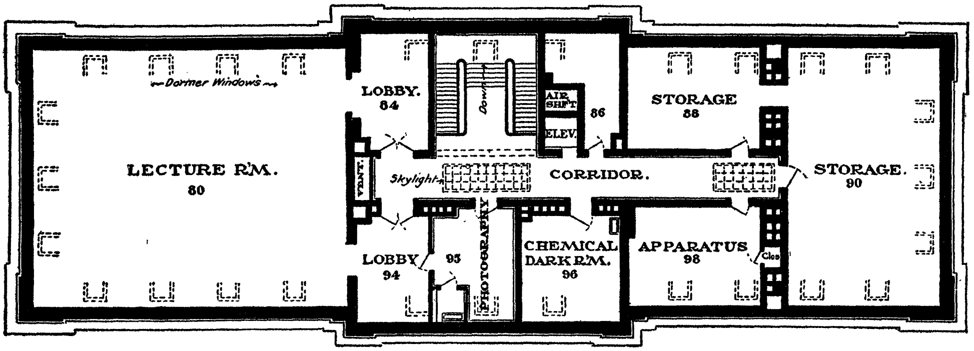
Rooms 1 and 2 will be used as research laboratories for weights and measures, and 21, 22 and 23 will be used for testing weights and measures. This includes masses from a milligram to twenty kilograms, or from a grain to fifty pounds; standards of length up to a meter or a yard; and measures of volume, such as pipettes, burettes, standard flasks, of various capacities up to cubic-foot bottles. Rooms 11, 12, 13 and 14 will be used for research and testing in connection with various methods of making precise mass, length and capacity measurements, including optical methods and optical instruments. Rooms 31 and 32 will be used as general research laboratories, and Room 34 will be used as a laboratory for testing watches, chronometers, clocks, tuning forks and other timepieces.

Rooms 8 and 9 will be used for research and testing of thermometers and pyrometers for measuring temperatures outside the range of mercury thermometers. This will include the use of thermo-couples, platinum thermometers, gas thermometers and commercial pyrometers for high temperatures, such as those used in ovens and furnaces, and of gas, platinum, pentane, toluene and other thermometers for low temperatures down to that of liquid air.

Rooms 16, 17, 18 and 19 will be used for investigation and testing of resistance standards, resistance boxes, and shunts;



4th. FLOOR PLAN.



ATTIC FLOOR PLAN.

standard cells, and instruments used in measuring resistance and electromotive forces. These standards are fundamental to all electrical measurements, and special stress has been laid upon the development of this department.

Rooms 28 and 29 are to be employed for the investigation and testing of standards of capacity and inductance, and for studying problems in which capacity and inductance are involved. Rooms 36, 38 and 39 are to be used for research in other alternating- or direct-current problems.

The third floor provides accommodation at one end for a museum, apparatus and supplies; at the other end for the library and reading room, and in the central portion for the offices of administration. These rooms were placed on the third floor, in order to devote the two lower floors to laboratory purposes—where freedom from mechanical disturbance is of greater importance. The library measures 28 × 48 feet.

Room 61 on the fourth floor is to be devoted to researches on photometric standards, work which will be carried on in connection with the photometric laboratory of the mechanical building. Room 60 will accommodate the work on mercurial thermometers, including ordinary thermometers, precision thermometers, and clinical thermometers. Room 70, at the east end of this floor, is a large general laboratory which may be used for either physical or chemical investigations. The other rooms of this floor will be fitted up as a chemical laboratory, for work in analytical, physical and electrochemistry.

On the fifth floor is to be located a commodious lecture room, which may also be used to some extent as a laboratory; an apparatus room, and two or three storage rooms.

In addition to the heating and ventilating system, in which each room has a flue for supplying fresh air (heated or cooled as the case may be), and a second flue for carrying air away from the room, there is to be a separate exhaust system with a connection to each laboratory room, and also to each toilet room, the storage battery rooms, the hoods of the chemical laboratories, etc. These exhaust flues open down into the basement, where they are gathered into one large duct, which is carried through the tunnel to an exhaust fan in the engine room. This fan will run at a comparatively high speed, and will insure a positive draft at each inlet to the system.

Much thought has also been given to such features of the laboratory equipment as plumbing, work tables, cases, etc., but space forbids giving any particulars.

EDWARD B. ROSA.
NATIONAL BUREAU OF STANDARDS,
WASHINGTON, D. C.

AMERICAN PHILOSOPHICAL ASSOCIATION.

OVER fifty members attended the second meeting of the American Philosophical Association, held in Washington, in affiliation with the American Society of Naturalists and the other societies meeting under the auspices of the American Association for the Advancement of Science, on December 30 and 31. The affiliation of the association with the scientific societies at this its first meeting following the meeting last Easter, at which it was organized, is significant of the close relation felt to exist between philosophy and the special sciences, a significance emphasized by the fact that a member of the association was this year president of the Society of Naturalists. Probably there was something of the old contempt for abstract speculation on the part of men of science in the good-natured laughter which broke out at the dinner of the naturalists, when it was announced that the psychologists and phi-